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4.3 CALIBRATION OVERVIEW OF LUMPED LAKE OKEECHOBEE SERVICE AREA BASINS

The South Florida Water Management Model (SFWMM) requires demand/runoff time series input for (among others) the Caloosahatchee (C-43), St. Lucie (C-44), S4, Lower Istokpoga, and North/Northeast Lake Shore Basins. These basins are geographically close to each other, falling within Lake Okeechobee Service Area (LOSA). Additionally, they share common land use types (predominantly agriculture or natural systems) and land management practices. A review of available data for these basins indicated that the Caloosahatchee Basin has the most reliable and up-to-date flow information. The decision was therefore made to calibrate an implementation of the AFSISRS/WATBAL model for the Caloosahatchee Basin (as conceptually outlined in Section 3.2) for the period 1991-2000. Parameters derived from the Caloosahatchee Basin calibration are then used in modeling the other LOSA basins for regional modeling purposes. Additional calibration efforts were also performed for geographic areas that included the Seminole Brighton and Seminole Big Cypress Reservation lands. This was due to the need to ensure that demand estimations as modeled were consistent with water rights compact entitlement volumes protected by Florida state law. The following sections will describe these independent lumped-system calibration efforts.

4.3.1 Calibration of the Caloosahatchee Basin

Data for use in the Caloosahatchee AFSIRS/WATBAL model comes from a wide variety of sources. As previously stated, a calibration period of 1991-2000 was used. Climate data was taken from available rainfall (Section 2.2) and potential evapotranspiration (PET) (Section 2.3) data sets created for the SFWMM. Historical flow data for boundary structures (S-77, S235 and S-79) were obtained from the SFWMD's DBHYDRO database. There was a substantial increase in irrigated lands within the Caloosahatchee Basin over the calibration period. AFSIRS/WATBAL modeling is able to simulate the changes in irrigation demands and runoff that result from changing land uses. For calibration, historic land use-over-time tables were developed for each irrigation basin. District land use coverages were used to establish 1988 (SFWMD 1994), 1995 and 2000 (SFWMD 2002) land use. Land use for intermediate years was interpolated based on historic countywide crop land use data published by Florida Agricultural Statistics Service (FASS).

The process for calibration of the AFSIRS/WATBAL model is iterative and consists of several steps. Parameters for calibration of the model include two global irrigation parameters, five parameters each for three types of nonirrigated lands and monthly Kc parameters for evapotranspiration estimation for each land use type. The calibration strategy is to select reasonable values for each parameter, run the model, and evaluate the results using several goodness-of-fit (GOF) measures. The GOFs were used to compare the simulated demand and runoff to the measured flows over the calibration period of 1991-2000. Model parameters were adjusted after each run for a subsequent attempt to obtain the best GOFs. An additional check is required after each iteration to ensure that in addition to appropriate basin-scale results, the individual land use performances were also realistic (e.g. no crop had 70 inches of ET demand, rangeland did not flood to 5 feet, etc.).

The final results of the iterative process yielded calibrated parameters as shown in Tables 4.3.1.1, 4.3.1.2 and 4.3.1.3. Calibration summaries and GOF analysis of agricultural demands are presented in Table 4.3.1.4 and Figures 4.3.1.1 to 4.3.1.2. Results of calibration and GOF analysis of watershed runoff are presented in Table 4.3.1.5 and Figures 4.3.1.4 to 4.3.1.6. Table 4.3.1.6 relates the individual water budget summaries for each of the calibrated land use types for a representative sub-basin (ECAL-D).

In general, the results of the calibration are extremely good, especially considering the amount of uncertainty associated with climate, flow, and land use data estimation. Correlations of modeled to measured data are high for both demand and runoff estimation. In addition, the model calibration shows very little bias and is able to reproduce the seasonal variability observed in the measured data. Additionally, the performances of the individual land use types, as presented in Table 4.3.1.6, are within the expected ranges of behavior. Additional, more specific, comments related to the calibration results are presented in bullet form below.

- The value for EFF1of less than 100% in Table 4.3.1.1 indicates that there exists water use within the basin not directly related to crop irrigation requirements. This extra demand (resulting from transmission losses, incidental irrigation, etc.) ends up in the atmosphere but the processes are not modeled.
- The local storage term (STOR1) presented in Table 4.3.1.1 is approximately 0.10 inches which represents a small (approximately 6 inch) water table variation.
- Kc values as derived in Table 4.3.1.3 are intended to be used in conjunction with wet marsh PET estimations by the simplified temperature-based method as used in the SFWMM (Irizarry, 2003b). These Kc values were capped at a maximum value of 1.10 for open water as is consistent with the assumption in the SFWMM.
- AFSIRS/WATBAL is a hydrologic, not a hydraulic model and should not be used to estimate peak runoff rates. However, it can predict total storm runoff. GOF measures for runoff are calculated on five-day moving average daily values.
- Since evaluation of demand estimates is tied to regulatory (1-in-10 months) or more long term time steps, GOF measures for demand are presented on a monthly basis.
- The cumulative demand and runoff traces in Figures 4.3.1.3 and 4.3.1.6 indicate that modeled demand and runoff follow the same pattern as measured data over the period of record. While the model tends to slightly under-predict demand in earlier years and then over-predict in later years, this is most likely due to inaccurate growth estimate in the land use data.

Based on the results and the success of the Caloosahatchee Basin calibration exercise, it is appropriate to apply the AFSIRS/WATBAL V3.0 model with the Caloosahatchee Basin calibrated parameters to all LOSA basins in regional modeling efforts.

Table 4.3.1.1 Caloosahatchee Calibrated Values for AFSIRS Water Budget Model Parameters

Irrigation efficiency1 (consumptive use by plant /amount lost to air) [EFF1]	87%
Local Storage Depth (inches) [STOR1]	0.1
Drainage capacity (inches/day) [CAP1]	7.0
Storage coefficient (day) [COEF1]	7

Table 4.3.1.2 Caloosahatchee Calibrated Values for WATBAL Model Parameters

	Rangeland	Upland Forest	Wetlands
Plant available water (PAW) capacity [inches]	0.8	1.6	2.2
Drainable storage capacity (CAP1) [inches]	7.0	7.0	1.0
Storage coefficient (COEF1) [days]	7	7	8
Total groundwater storage [inches]	7.0	7.0	5.0
Root zone depth [inches]	11.4	22.9	5.5

Table 4.3.1.3 Caloosahatchee Calibrated Values for Monthly Potential Evapotranspiration Correction Factors (Kc)

Month	citrus	Cane	Veg	pasture	up forest	wetlands
1	0.71	0.61	0.28	0.54	0.58	0.67
2	0.66	0.57	0.25	0.55	0.59	0.63
3	0.61	0.51	0.87	0.55	0.59	0.57
4	0.64	0.59	0.58	0.75	0.68	0.65
5	0.87	0.88	0.87	0.89	0.89	0.93
6	0.98	0.98	0.96	0.99	1.04	1.04
7	1.02	1.07	1.00	1.03	1.08	1.10
8	0.83	0.90	0.89	0.88	0.93	0.96
9	0.93	1.00	0.29	0.91	0.96	1.06
10	0.99	1.00	0.32	0.83	0.82	1.06
11	0.84	0.80	0.99	0.60	0.70	0.85
12	0.82	0.72	0.63	0.53	0.57	0.77

Table 4.3.1.4 Caloosahatchee Measures of Goodness of Fit for Calibration of AFSIRS Water Budget Model

Average Annual Demand	
Demand – Modeled	86,407 ac-ft/yr
Demand – Measured	84,367 ac-ft/yr
Goodness of Fit	
Model - Measured Error	2,040 ac-ft/yr
Demand (Model) - Demand (Measured) / Demand (Model)	2.36%
Slope of Modeled - Measured Demand	0.962
Regression Coefficient of Modeled - Measured Demand	0.813
Pearson Correlation Coefficient	0.902
Modeled Bias	-170 ac-ft
Root Mean Squared Error	4,007 ac-ft

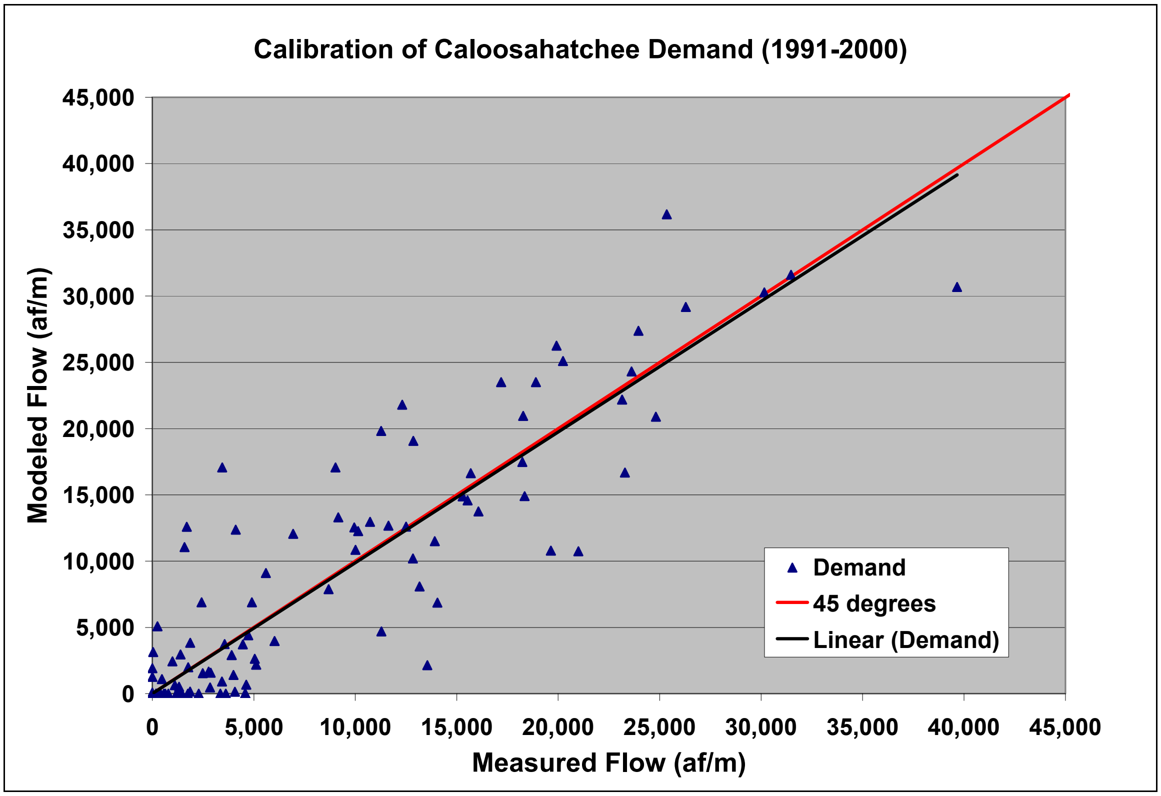

Figure 4.3.1.1 Measured vs. Modeled Caloosahatchee Demand

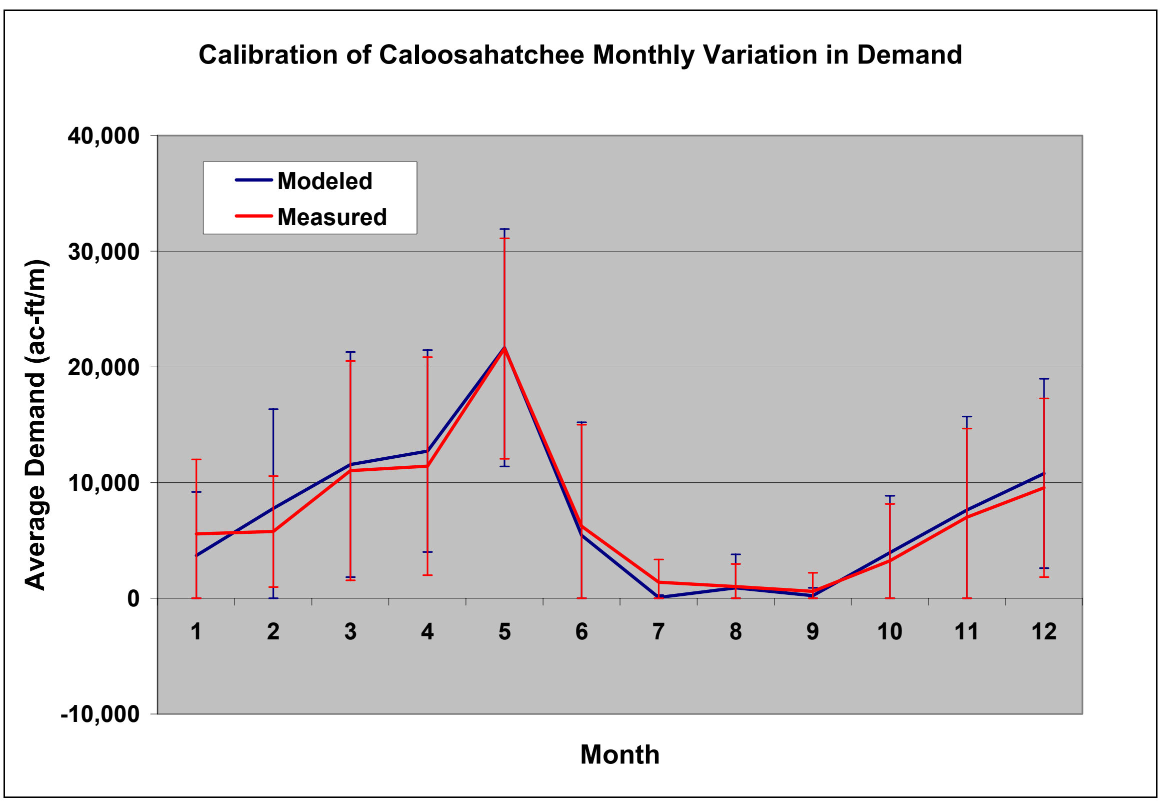

Figure 4.3.1.2 Seasonal Variability in Caloosahatchee Demand

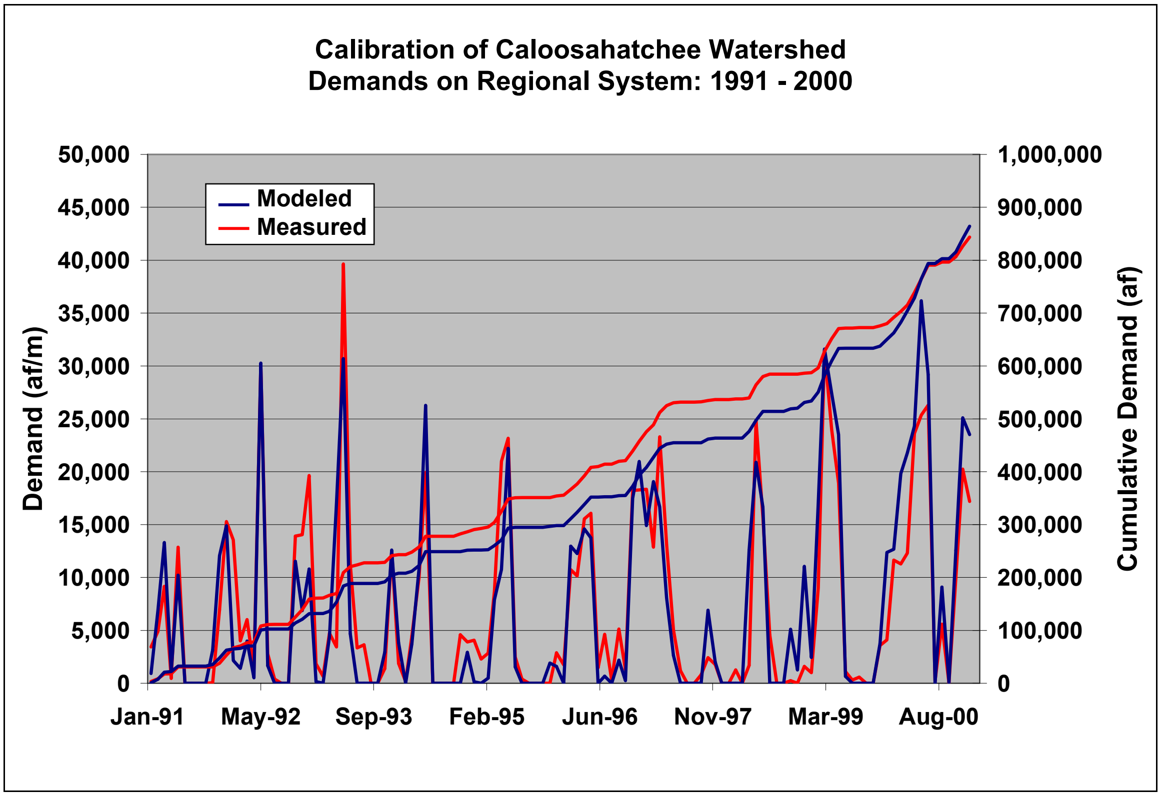

Figure 4.3.1.3 Time Series of Monthly Caloosahatchee Demand and Accumulation

Table 4.3.1.5 Caloosahatchee Measures of Goodness of Fit for Calibration of WATBAL Model

Average Annual Runoff	
Runoff – Modeled	803,863 ac-ft/yr
Runoff – Measured	799,598 ac-ft/yr
Goodness of Fit	
Model - Measured Error	4,265 ac-ft/yr
Runoff (Model) - Runoff (Measured) / Runoff (Model)	0.53%
Slope of Modeled - Measured Runoff	0.973
Regression Coefficient of Modeled - Measured Runoff	0.825
Pearson Correlation Coefficient	0.908
Modeled Bias	12 ac-ft
Root Mean Squared Error	1,477 ac-ft

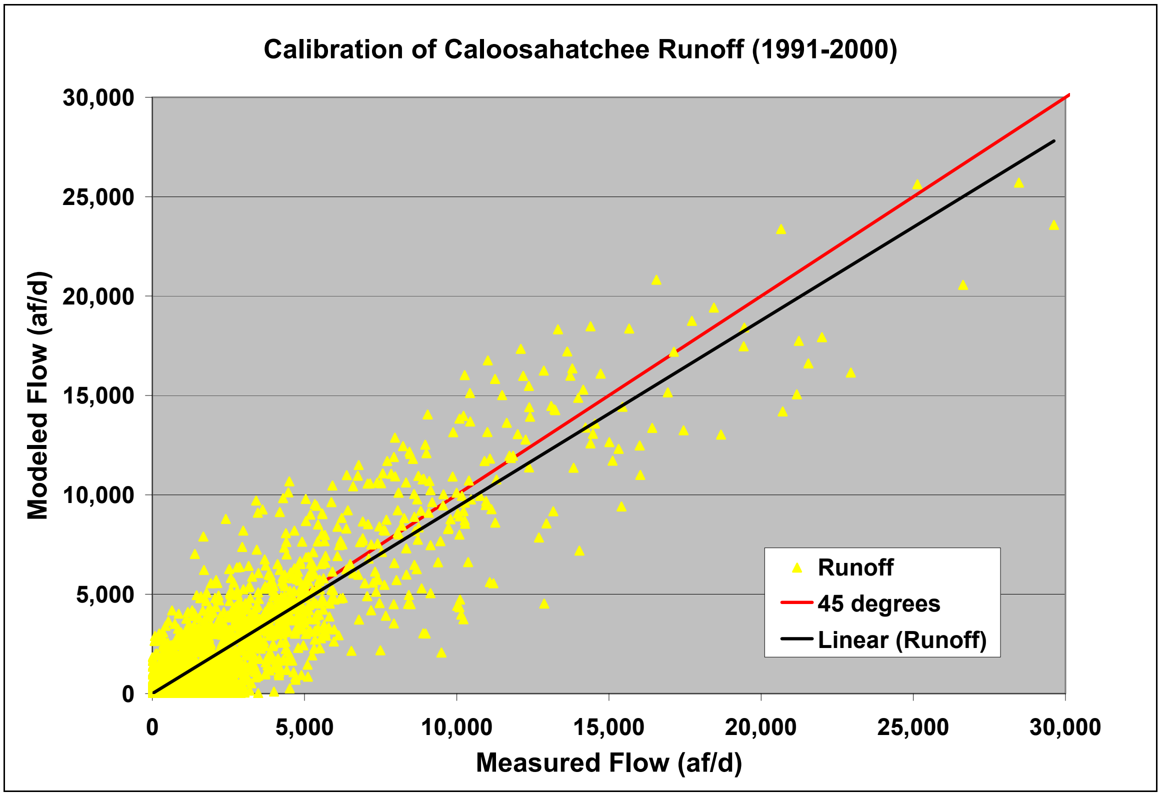

Figure 4.3.1.4 Measured vs. Modeled Caloosahatchee Runoff

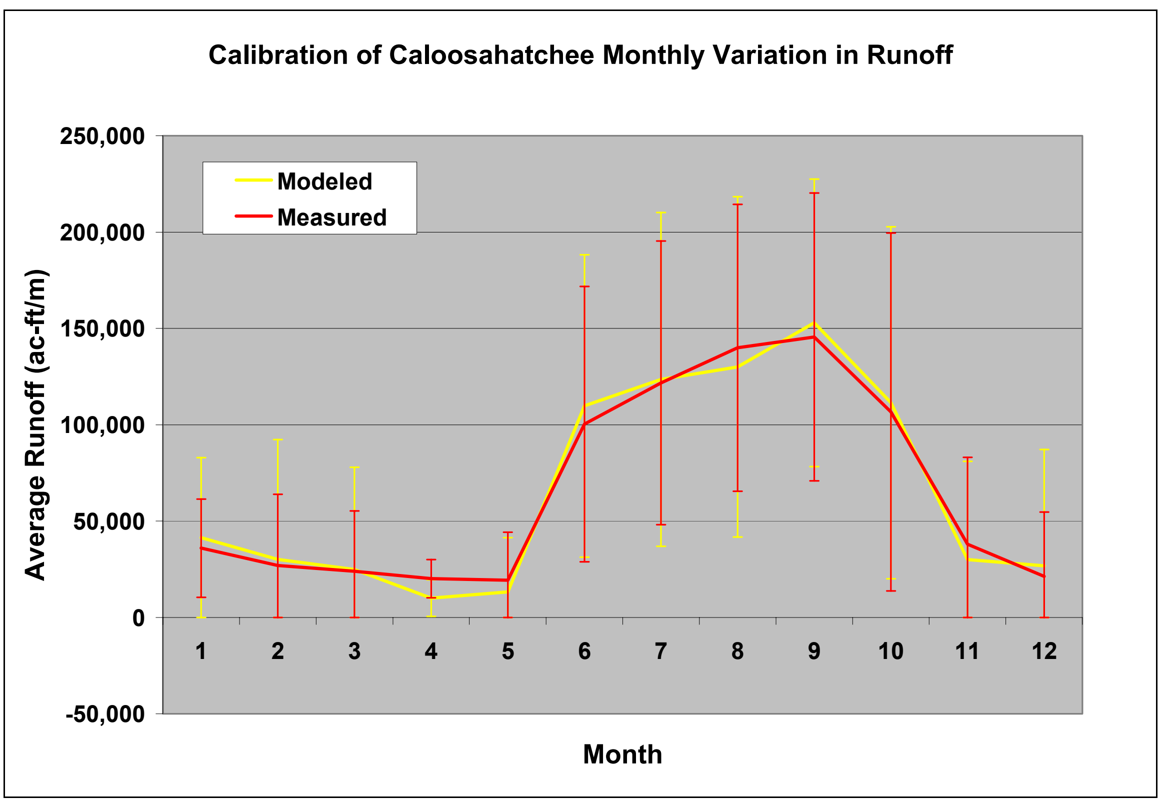

Figure 4.3.1.5 Seasonal Variability in Caloosahatchee Runoff

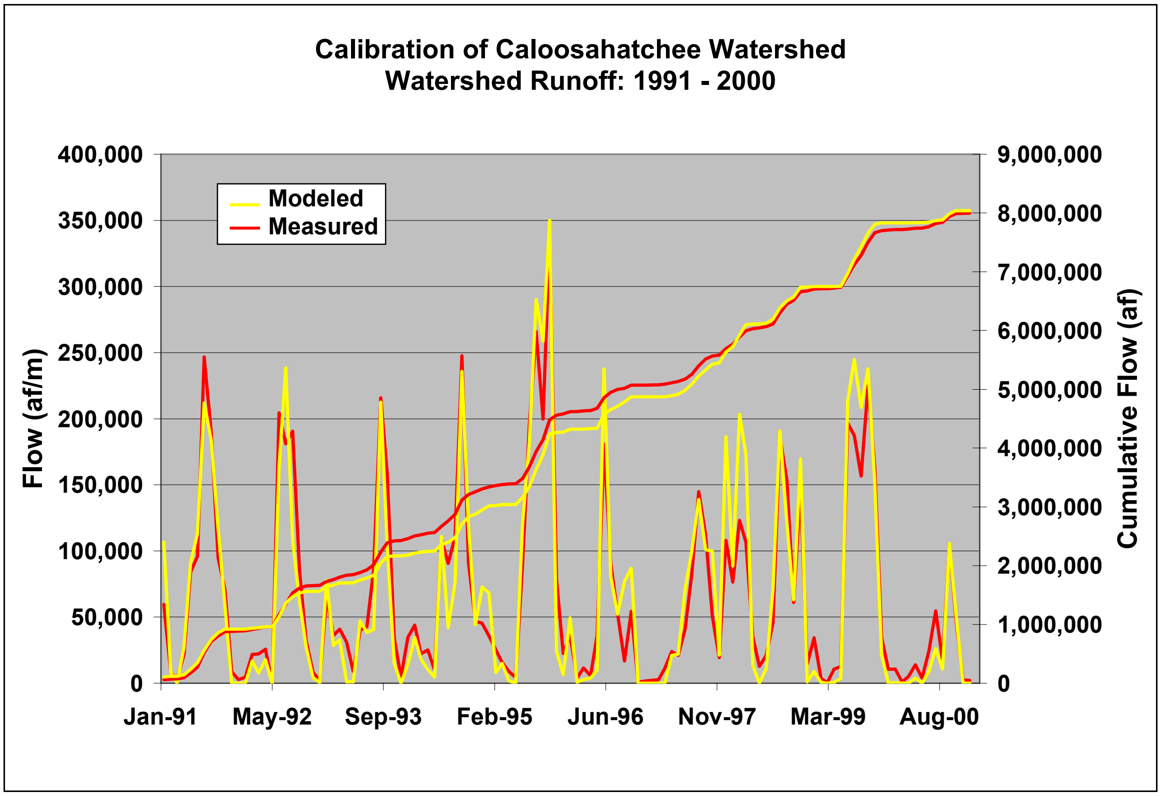

Figure 4.3.1.6 Time Series of Monthly Caloosahatchee Runoff and Accumulation

Table 4.3.1.6 Caloosahatchee Water Budget Summaries for Calibrated Land Use Types (ECAL-D sub-basin)

	Land Use						
	Citrus - crownflood irrigated	**Citrus - microjet irrigated**	**Sugar cane-subseepage irrigated**	**Tomatoes - microspray irrigated**	**Range-land**	**Upland Forest**	**Wetland**
Rain [in/yr]	50.6	50.6	50.6	50.6	50.6	50.6	50.6
Actual Evapo-transpiration [in/yr]	48.8	48.7	47.9	45.2	34.2	37.5	40.6
AFSIRS Irrigation [in/yr]	15.9	6.8	16.9	10.4	-	-	-
AFSIRS Runoff [in/yr]	17.7	8.7	19.6	15.8	-	-	-
Drainage and Recharge [in/yr]	-	-	-	-	16.4	13.1	10.0
Maximum Flooding Depth [in]	-	-	-	-	0.0	2.4	9.9

4.3.2 Calibration of the Brighton Seminole Reservation and Lower Istokpoga Basin

The Brighton/Istokpoga calibration implementation of the AFSIRS/WATBAL model is conceptualized as a single basin model (as conceptually outlined in Section 3.2) covering the lands between S-70/S-75 and S-71/S-72 that influence the regional system. This area includes the Seminole Brighton Reservation as well as additional irrigated and non-irrigated lands. In general, reliable flow and land use data in the defined basin is limited. While flow data exists for the last several decades, it contains large periods of missing data and a water budget analysis created by utilizing these flows shows several months of unrealistically high or low demand conditions. Land use data for the basin is also in short supply, especially before the 1995 FLUCCS land use coverage. Due to these data limitations, a calibration period of 1995-2000 was selected. While this is a relatively short period of simulation, it should prove sufficient for parameter estimation, especially since the model will be applied with land use assumptions consistent with circa-2000 conditions. Once the calibration period was selected, historical flow data for boundary structures (S-70, S-71, S-72, S-75, G207 and G208) was obtained from the SFWMD's DBHYDRO database. Additionally, a historic land use table was developed based on a combination of District land use coverage for 1995 and 2000 permitted agricultural land use as used in Supply Side Management implementation (SFWMD, 2002).

Once data had been collected, an iterative calibration process was attempted in a manner similar to that undertaken for the Caloosahatchee Basin AFSIRS/WATBAL model (Wilcox 2003a, presented in Section 4.3.1). The goal of the Brighton/Istokpoga calibration was to be able to match a measured demand condition as closely as possible. Due to this consideration and also taking into account the uncertainty in measured data for the Brighton/Istokpoga model, many of the Caloosahatchee Basin calibrated model parameters were incorporated without modification. In fact, only two of the AFSIRS/WATBAL model parameters were modified during calibration. These demand related calibration terms were the irrigation efficiency [EFF1] and the Local Storage Depth [STOR1]. The final results of the iterative process yielded calibrated parameters as shown in Tables 4.3.2.1 and 4.3.2.2 (with rangeland Kc factors from Caloosahatchee Basin being applied to pasture/sod in Brighton/Istokpoga). Calibration summaries and Goodness of Fit (GOF) analysis of agricultural demands are presented in Table 4.3.2.3 and Figures 4.3.2.1 to 4.3.2.3.

Table 4.3.2.1 Brighton/Istokpoga Calibrated Values for AFSIRS Water Budget Model Parameters

Irrigation efficiency1 (consumptive use by plant / amount lost to air) (EFF1)	60%
Local Storage Depth (STOR1) [inches]	0.2
Drainage capacity (CAP1) [inches/day]	7.0
Storage coefficient (COEF1) [day]	7

Table 4.3.2.2 Brighton/Istokpoga Values for Monthly Potential Evapotranspiration Correction Factors (Kc) as Calibrated in Caloosahatchee Basin

Month	citrus	sugarcane	pasture/sod
1	0.71	0.61	0.54
2	0.66	0.57	0.55
3	0.61	0.51	0.55
4	0.64	0.59	0.75
5	0.87	0.88	0.89
6	0.98	0.98	0.99
7	1.02	1.07	1.03
8	0.83	0.90	0.88
9	0.93	1.00	0.91
10	0.99	1.00	0.83
11	0.84	0.80	0.60
12	0.82	0.72	0.53

Table 4.3.2.3 Brighton/Istokpoga Measures of Goodness of Fit for Calibration of AFSIRS Water Budget Model

Average Annual Demand	
Demand – Modeled	49,723 ac-ft/yr
Demand – Measured	49,514 ac-ft/yr
Goodness of Fit	
Model - Measured Error	209 ac-ft/yr
Demand (Model) - Demand (Measured) / Demand (Model)	2.36%
Slope of Modeled - Measured Demand	0.933
Regression Coefficient of Modeled - Measured Demand	0.507
Pearson Correlation Coefficient	0.712
Modeled Bias	-17 ac-ft
Root Mean Squared Error	3,032 ac-ft

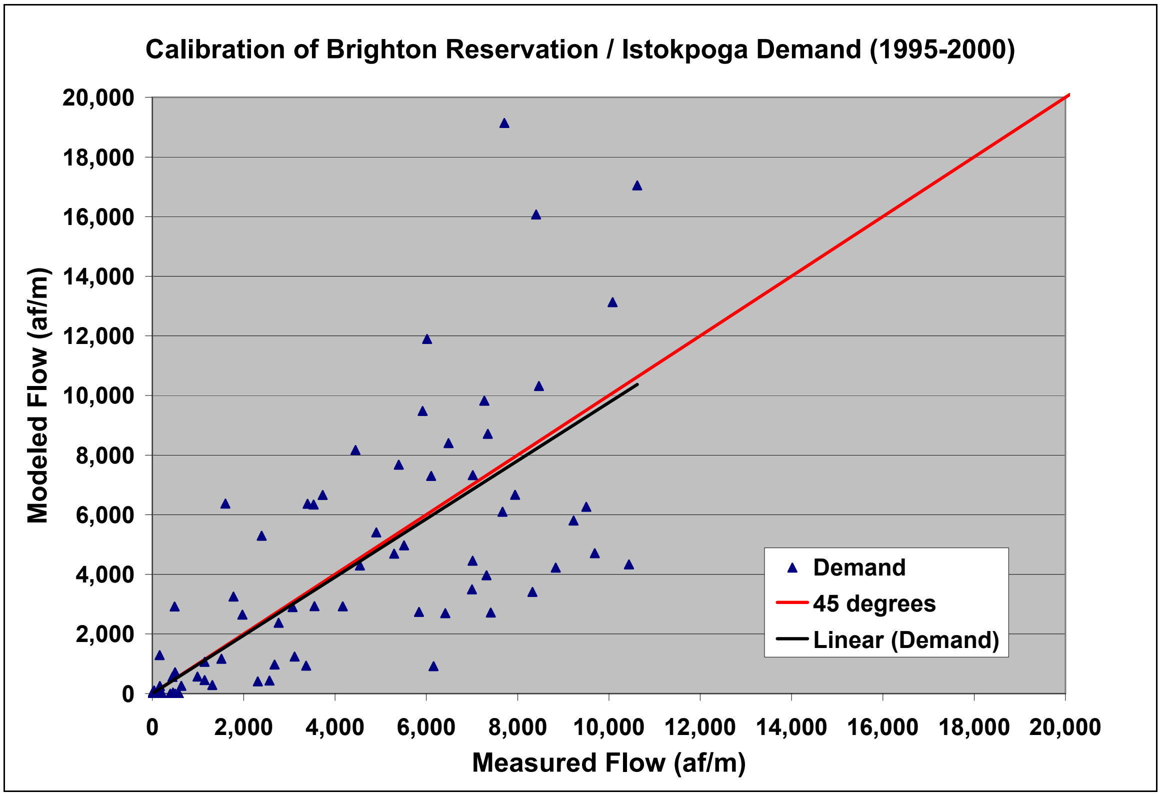

Figure 4.3.2.1 Measured vs. Modeled Brighton/Istokpoga Demand

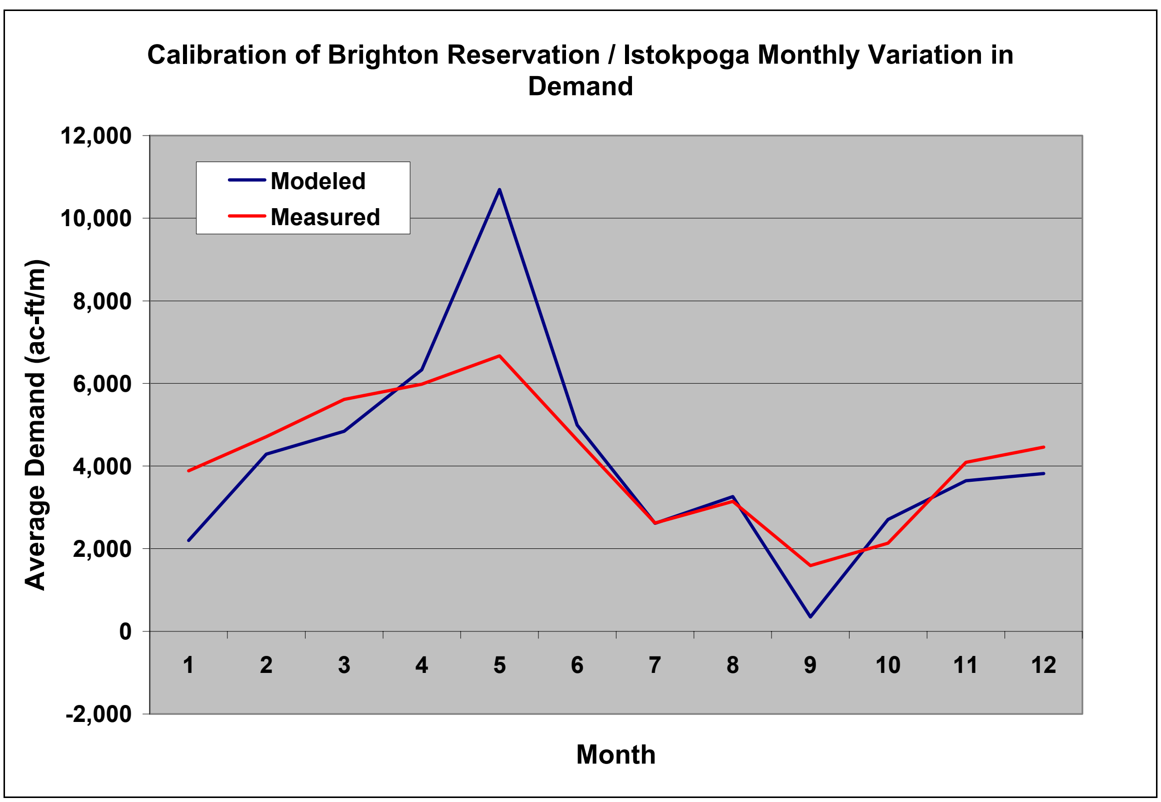

Figure 4.3.2.2 Seasonal Variability in Brighton/Istokpoga Demand

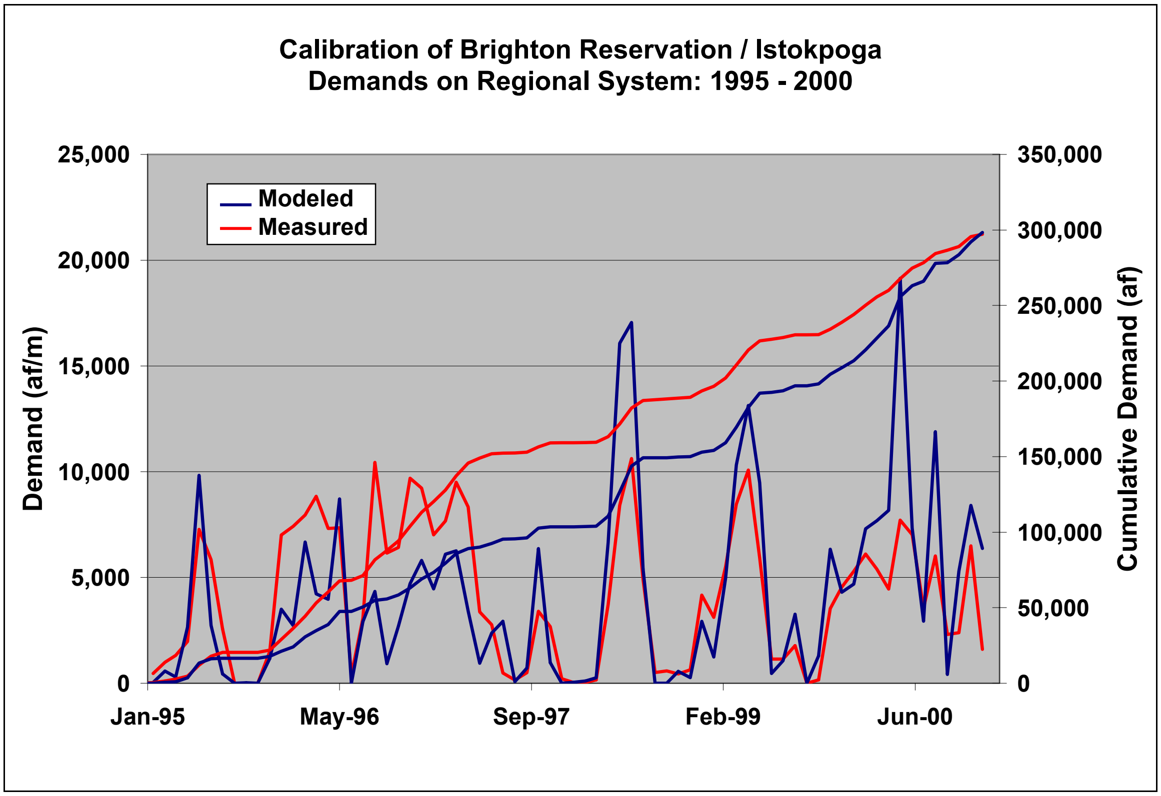

Figure 4.3.2.3 Time Series of Monthly Brighton/Istokpoga Demand and Accumulation

In general, results of this calibration exercise are acceptable, although not as good as those observed in the Caloosahatchee Basin for AFSIRS/WATBAL V3.0. The main strength of the calibrated model is its ability to predict the timing of when periods of demand occur. Calibration of the Brighton/Istokpoga Basin to both timing and magnitude of demand was significantly more difficult than for the C-43 due to the previously outlined data issues in conjunction with the relatively small magnitude of demand in the basin. Additional, more specific, comments related to the calibration results are presented in bullet form below.

- The calibrated EFF1 term was lowered to 60% (from 87% in the Caloosahatchee Basin) indicating an increase in un-captured loss terms. However, this term still falls well within the range of reasonability and is on the same order as previous modeling exercises for the Caloosahatchee Basin with AFSIRS/WATBAL V2.0 for the CWMP plan (58%).
- The change in STOR1 from 0.1 inches to 0.2 inches represents increased uncertainty in water table fluctuation.
- The correlation of measured to modeled demand is good overall, with the exception of a few outlier points - May 2000 in particular. In this month, the modeled demand is over double the magnitude of the measured basin demand. This inconsistency is clearly evident in both the scatter plot (Figure 4.3.2.1) and the seasonal variability (Figure 4.3.2.2), which shows a marked bias in "overestimation" of May demand. It is strange that measured demand is not higher given that May 2000 was one of the driest months in history and this observation may point to problems with the measured data.
- The model tends to slightly under-predict demand in earlier years and then over-predict in later years - this is most likely due to inaccurate estimate in the land use data which

was assumed to be constant during the calibration period due to the lack of reliable data related to land use growth.

Based on the results of the Brighton/Istokpoga calibration exercise, it seems appropriate to apply the AFSIRS/WATBAL V3.0 model in regional modeling efforts associated with demand estimation for the Brighton Reservation.

4.3.3 Calibration of the Big Cypress Seminole Reservation and Feeder Canal Basin

Due to the interrelationship between the Big Cypress Seminole Reservation and the Feeder Canal Basin (as described in Section 2.6.3), two separate AFSIRS-WATBAL models were implemented during a joined calibration effort: 1) a model of the Big Cypress Reservation (BCR) lands, and 2) a model of the Feeder Canal Basin. Consistent parameters between the two areas were derived during calibration and were applied in both model implementations.

Big Cypress Seminole Reservation Basin-Scale Demands

The AFSIRS-WATBAL model was used to estimate basin-scale net irrigation demands for the Big Cypress Reservation. The AFSIRS portion of the model was used to estimate field-scale irrigation requirements for four major land uses (Table 4.3.3.3) as specified in the Work Plan Authorization. The WATBAL portion of the model transforms the field-scale net irrigation demands into basin-scale demands by accounting for local basin storage and basin efficiency, which includes losses to air and water conveyance losses. Non-irrigated lands in the BCR were not incorporated into the model and so did not contribute toward meeting needs in the irrigated lands.

Due to the lack of historical water use data, the modeled BCR demand had to be compared with the permitted demands from the Work Plan Authorization. Using an iterative process, the 4 basin parameters shown in Table 4.3.3.1 were modified until the 2-in-10 monthly demand matched the permitted demands (Table 4.3.3.2). Of notable interest, the efficiency term had to be lowered to 50% to be able to match the permitted demands. In addition, land use-specific performance was checked for reasonableness (Table 4.3.3.3).

Table 4.3.3.1 Big Cypress Reservation Calibrated Values for AFSIRS Water Budget Model Parameters

Irrigation efficiency1 (consumptive use by plant / amount lost to air) (EFF1)	50%
Local Storage Depth (STOR1) [inches]	0.05
Drainage capacity (CAP1) [inches/day]	7.0
Storage coefficient (COEF1) [day]	6

Table 4.3.3.2 Big Cypress Reservation Comparison of Modeled Demands to Work Plan Entitlement for the period 1965-2000

Average Annual Demand – Modeled	28,509 ac-ft/yr
Modeled 1-in-5 monthly demand	8,157 ac-ft/mo (2,659 mgm)
1-in-5 monthly demand from Work Plan Authorization	7,994 ac-ft/mo (2,606 mgm)

Table 4.3.3.3 Big Cypress Reservation Water Budget Summaries for Calibrated Land Use Types (1991-2000 calibration period)

	Land Use			
	Citrus - crownflood irrigated	**Citrus - microjet irrigated**	**Tomatoes – microspray irrigated**	**Irrigated Pasture**
Acreage (acres)	1,730	494	1,151	10,441
Rain (in/yr)	53.6	53.6	53.6	53.6
Actual Evapo-transpiration (in/yr)	51.9	52.1	44.3	46.8
AFSIRS Irrigation (in/yr)	21.1	6.5	10.2	12.8
AFSIRS Runoff (in/yr)	22.9	8.0	19.5	19.6

Feeder Canal Basin Runoff

The AFSIRS-WATBAL model for the Feeder Canal Basin was calibrated to monthly runoff totals as measured at S-190. To get rid of the effect of structure operations in the measured discharges at S-190, it was necessary to calibrate to monthly runoff totals. The calibration period was selected as 1991-2000, however only a single land use snapshot (circa 2000) was used in the calibration. As shown in Table 4.3.3.6, both irrigated and non-irrigated lands were included in the model. The global irrigation parameters shown in Table 4.3.3.1 were used in the Feeder Canal Basin model. Using an iterative procedure, five parameters were calibrated for each of the three non-irrigated land uses (Table 4.3.3.4).

Table 4.3.3.5 and Figures 4.3.3.1 and 4.3.3.2 show the model performance for the 1991-2000 calibration period. From these figures, it can be observed that the model captures the monthly and interannual variability in runoff reasonably well. The correlation of measured to modeled monthly runoff is also reasonably good ($R = 0.82$). However, it is evident that the model underestimates runoff by approximately 6%. One particular event (December 1994) is responsible for about two-thirds of the cumulative runoff error over the calibration period. The year 1994 was an unusually wet year with higher than normal rainfall occurring during the typically dry months of November and December. Hurricane Gordon dropped more than 5 inches of rainfall over the area in November 1994. November of 1994 had a total of 6.2 inches of rainfall versus averages of 2.3 and 2.8 inches observed for the 1965-2000 and 1991-2000 periods, respectively. Average rainfall for December of 1994 was 9.9 inches compared to averages of 1.7 and 2.1 inches for the 1965-2000 and 1991-2000 periods, respectively. Measured runoff for December of 1994 was 67,722 ac-ft/mo while the model simulated 32,940 ac-ft/mo of runoff. This unusually wet event was identified from the beginning of the calibration; however, additional efforts to reduce the gap between modeled and observed runoff for this event were unsuccessful.

Table 4.3.3.6 summarizes the land use-specific performance, which was also checked for reasonableness. Figure 4.3.3.3 shows the seasonal variation in modeled demand for the Feeder Canal Basin. Due to lack of historical data, the modeled demand time series could not be verified. However, the time series of demand for the Feeder Canal Basin is not used by the SFWMM in any form.

Table 4.3.3.4 Feeder Canal Basin Calibrated Values for WATBAL Model Parameters

	Rangeland	Upland Forest	Wetlands
Plant available water (PAW) capacity [inches]	0.3	1.0	2.0
Drainable storage capacity (CAP1) [inches]	7.0	7.0	1.0
Storage coefficient (COEF1) [days]	6	8	7
Total groundwater storage [inches]	7.0	7.0	5.0
Root zone depth [inches]	4.3	14.3	5.0

Table 4.3.3.5 Feeder Canal Basin Measures of Goodness of Fit for Calibration of WATBAL Model (1991-2000 period)

Average Annual Runoff	
Runoff – Modeled	84,863 ac-ft/yr
Runoff – Measured	90,113 ac-ft/yr
Goodness of Fit	
Model - Measured Error	-5,250 ac-ft/yr
Runoff (Model) - Runoff (Measured) / Runoff (Model)	-5.83%
Slope of Modeled - Measured Runoff	0.68
Regression Coefficient of Modeled - Measured Runoff	0.68
Pearson Correlation Coefficient	0.82
Modeled Bias	-437.6 ac-ft/mo
Root Mean Squared Error	5,900 ac-ft/mo

Table 4.3.3.6 Feeder Canal Basin Water Budget Summaries for Calibrated Land Use Types (1991-2000 calibration period)

	Land Use					
	Citrus - crownflood irrigated	**Citrus - microjet irrigated**	**Tomatoes – microspray irrigated**	**Range-land**	**Upland Forest**	**Wetland**
Acreage (acres)	1,608	3,752	9,000	24,419	7,468	18,107
Rain (in/yr)	53.6	53.6	53.6	53.6	53.6	53.6
Actual Evapo-transpiration (in/yr)	51.9	52.1	44.3	32.4	37.1	41.4
AFSIRS Irrigation (in/yr)	21.1	6.5	10.2	-	-	-
AFSIRS Runoff (in/yr)	22.9	8.0	19.5	-	-	-
Drainage and Recharge (in/yr)	-	-	-	21.3	16.5	12.2
Maximum Flooding Depth (in)	-	-	-	0.0	3.1	3.8

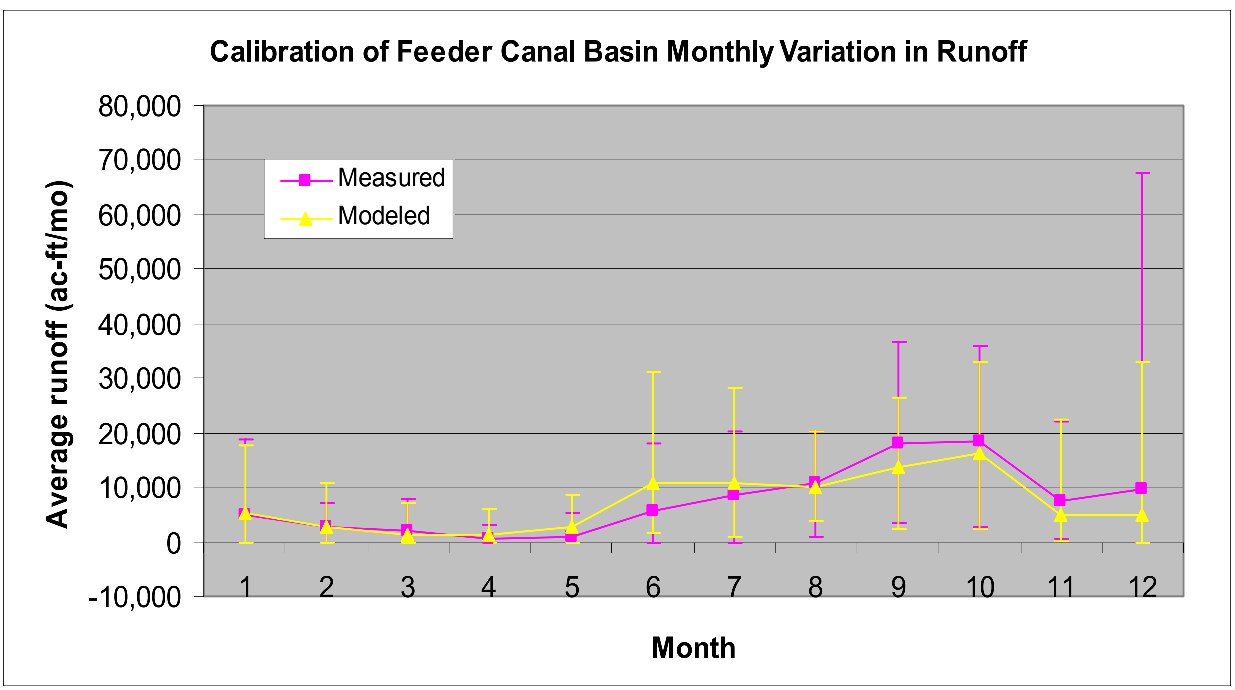

Figure 4.3.3.1 Seasonal Variability in Feeder Canal Basin Runoff

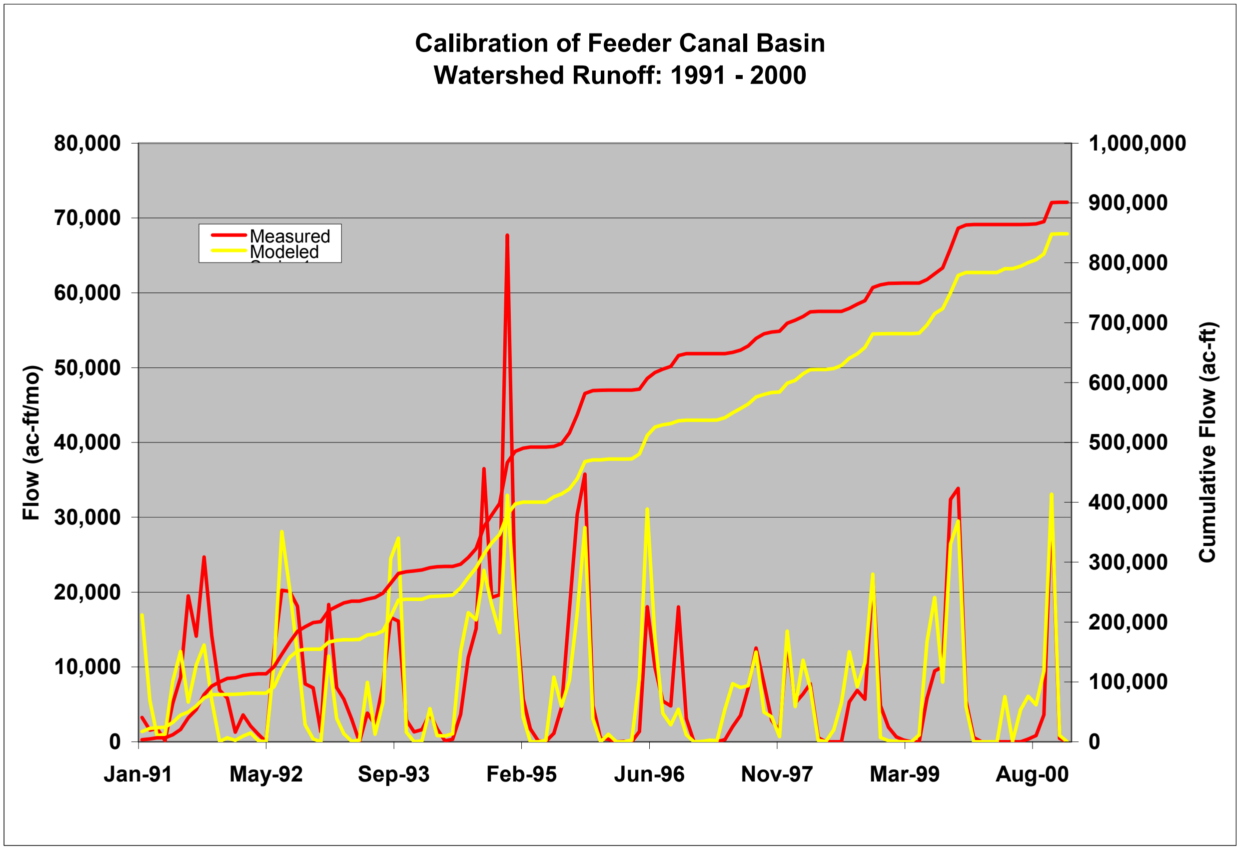

Figure 4.3.3.2 Time Series of Monthly Feeder Canal Basin Runoff and Accumulation

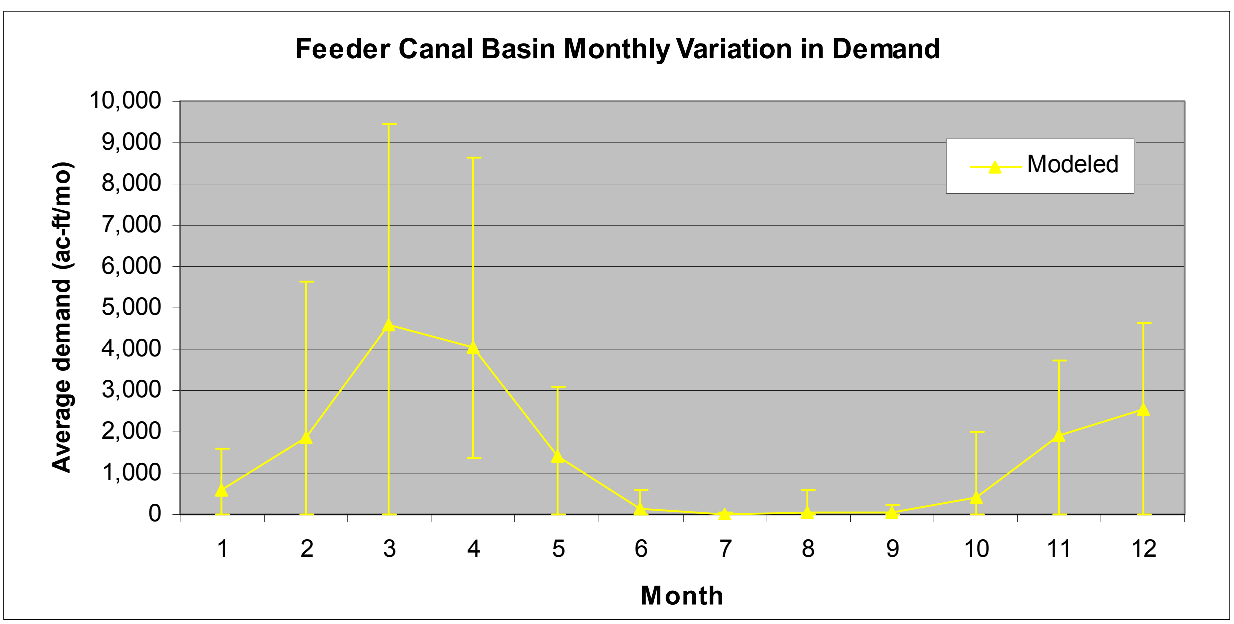

Figure 4.3.3.3 Seasonal Variability in Feeder Canal Basin Demand